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Frequency response characteristics of four a.m. receivers

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RESEARCH DEPARTMENT

FREQUENCY RESPONSE CHARACTERISTICS OF FOUR A.M. RECEIVERS

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D. Maurice

K. Hacking, B.Sc.
R.J.J. Roach, I.E.E.T.E.

Head of Research Department

(RA-46)

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Section	Title	Page
	SUMMARY	1
1.	INTRODUCTION	1
2.	THE RECEIVERS	1
3.	SELECTIVITY OF RADIO AND INTERMEDIATE FREQUENCY CIRCUITS	2
4.	ELECTRICAL RESPONSE	2
5.	ACOUSTICAL MEASUREMENTS	2
6.	OVERALL FREQUENCY RESPONSE	5
7.	ADJACENT-CHANNEL INTERFERENCE	5
8.	CONCLUSIONS	6
9.	REFERENCE	6

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SUMMARY

Measurements have been made to determine the amplitude-versus-frequency response characteristics of a selection of four domestic a.m. receivers currently used in the m.f./l.f. bands. The electrical and the acoustical characteristics were both investigated, and the results have been combined to produce the overall response. Subjective measurements of the adjacent-channel protection ratios of the receivers were obtained and shown to correlate well with their levels of response at the frequency associated with the adjacent-channel carrier spacing.

1. INTRODUCTION

The variation with frequency of the electrical and acoustical outputs of several medium- and low-frequency radio receivers were measured. This kind of basic information, especially the influence of the acoustical response, is useful in connection with transmitter planning and bandwidth standardization as well as indicating the degree of spectrum distortion associated with many existing receivers. The measured characteristics of four receivers are shown and their overall frequency responses compared with subjective measurements of adjacent-channel interference for these particular receivers.

2. THE RECEIVERS

General data relating to the four receivers, labelled A to D, are shown in Table 1. Three of the receivers were transistor portables of similar size while the fourth (D) was a table-model valve receiver in a large wooden cabinet. All were of British manufacture. Tone controls were set for the widest-range frequency response. The transistor portables incorporated ferrite-rod aerials but the test signal was injected into the external-aerial sockets provided. Except for receiver A, the internal aerials were inoperative during the measurement.

TABLE 1

Receiver Data

Receiver	Type	Approx. year of manufacture	Cabinet size (approx.)			Loudspeaker Size and Shape,
			Height, cm	Width, cm	Depth, cm	cm
A	Transistor portable	1968	14	25·5	8	18 x 9, elliptical
B	Transistor car/portable	1964	18	27	6·5	10, round
C	Transistor car/portable	1965	14·5	27·5	5·5	10, round
D	Valve Table-model	1953	43	56	19	18, round

3. SELECTIVITY OF RADIO AND INTERMEDIATE FREQUENCY CIRCUITS

The measured r.f./i.f. selectivity curves for the receivers are shown in Fig. 1, where the relative response is plotted against the deviation of the carrier frequency from the centre frequency of the passband. The centre frequency was adjusted to be in the region of 1 MHz and, for each receiver, the response has been averaged (geometric mean) for positive and negative deviations. Briefly, the method of measurement was to inject a single tone modulated carrier and adjust the input level, as the carrier frequency is varied, to maintain a constant a.f. output at the detector. The carrier was modulated to a depth of 40% by a 400 Hz tone source. The a.g.c. control was held constant at an appropriate level.

The main features of the r.f./i.f. selectivity characteristics are summarized in Table 2, where the total passband widths at the –4 dB and –20 dB levels are shown together with the relative responses at ±9 kHz from the centre frequency.

TABLE 2

R.F./I.F. Selectivity Measurements; Centre Frequency 1 MHz

Receiver	Total Passband widths, kHz		Response at ±9 kHz deviation relative to response at centre frequency, dB
	–4 dB level	–20 dB level	
A	5	9·3	–41
B	5·8	13·8	–29
C	6·4	18·4	–19·5
D	6·8	13·6	–30

At this stage, receiver A is the most selective and receiver C is the least selective; at ±9 kHz the difference between their respective levels of response amounts to more than 21 dB.

4. ELECTRICAL RESPONSE

For this measurement, the input signal was a single-tone modulated carrier (40% modulation depth) and the a.f. signal voltage across the speech coil of the loudspeaker was recorded, as the frequency of the modulating tone was varied from 50 Hz to 10 kHz. The frequency of the r.f. carrier was constant and its level was adjusted for each receiver to be equivalent to that of a radiated signal with a field strength at the receiver of the order of 10 mV/m. The receiver was tuned by ear using the criterion of minimum high-frequency noise. The volume control was adjusted for normal listening level.

Fig. 2 shows the measured electrical response characteristics of the four receivers as a function of modulation frequency; the relative response curves are normalized at 800 Hz.

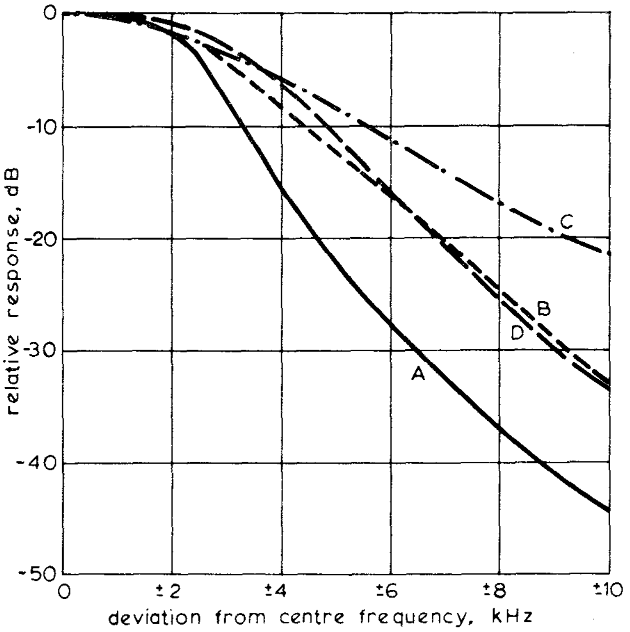

Fig. 1 - Measured r.f./i.f. selectivity

The electrical responses of all the receivers are substantially uniform over the range 200 Hz to 1200 Hz approximately. At a modulation frequency of 4·5 kHz the outputs have progressively fallen, depending on the receiver, to a level between 10 and 25 decibels below that at 800 Hz. Except for receiver C, which has a particularly slow fall-off, the relative responses have fallen to approximately –45 decibels at 9 kHz. Average rates of attenuation in electrical response over the interval 4·5 kHz to 9 kHz vary with receiver but are of the order of 25 dB per octave.

5. ACOUSTICAL MEASUREMENTS

The acoustical response of each loudspeaker in its cabinet was directly measured in an acoustically free-field environment[1] (anechoic chamber). The measurements were restricted to the axial responses, the pick-up microphone being positioned 1·5 metres from the receiver and approximately on the axis of the loudspeaker cone. The audio frequency test-tone (glide-tone) was applied directly to the speech coil and the acoustical intensity automatically recorded as a function of tone frequency over the range 50 Hz to 10 kHz.

An actual recording obtained for one of the receivers is shown in Fig. 3, where the rapidly fluctuating nature of the loudspeaker response will be noted; the sharp spikes on the recording are frequency markers. For comparison of the responses of the four receivers, however, smoothed versions of the original recordings were drawn and these are shown in Fig. 4. As with the electrical responses, the curves are normalized relative to the response at 800 Hz.

The general characteristics of the loudspeaker responses of the three transistor portables (A, B, C) are similar. Starting with relative responses of about –40 dB at 50 Hz (Fig. 4), the output increases quite rapidly to a level of

−10 dB at 200 Hz. Then follows a slower but progressive increase to a maximum value of approximately +5 dB somewhere in the range 3 kHz to 6 kHz. Finally, the response falls sharply, reaching a level of approximately −20 dB at 10 kHz. The response of the valve receiver, D, which has a larger loudspeaker and cabinet than the transistor portables, differs in that the average response over the range 200 Hz to 3 kHz is more uniform.

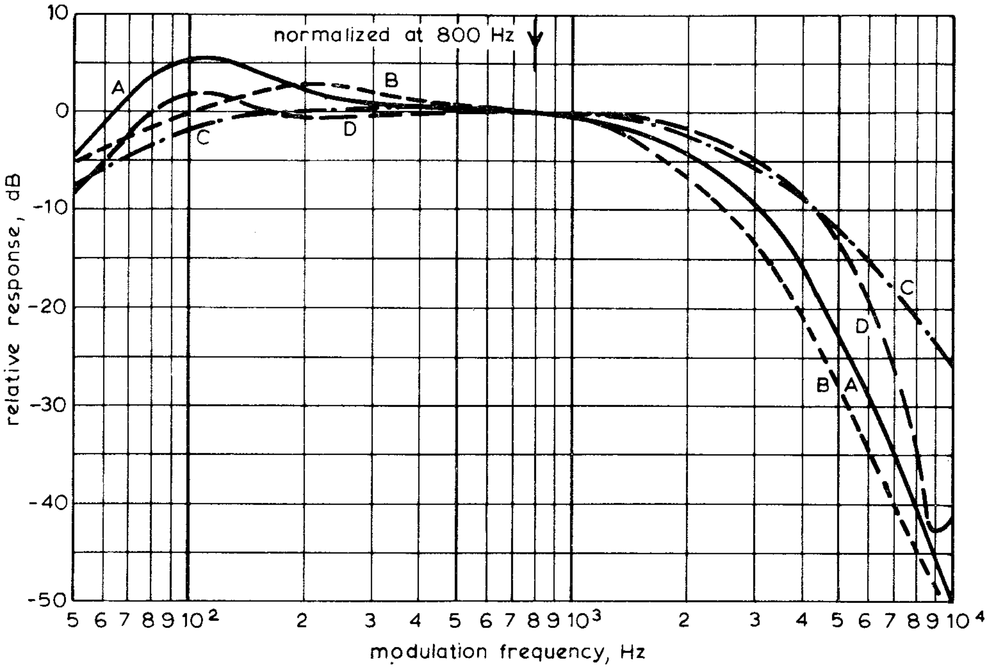

Fig. 2 - Measured electrical response of receivers (m.f. band)

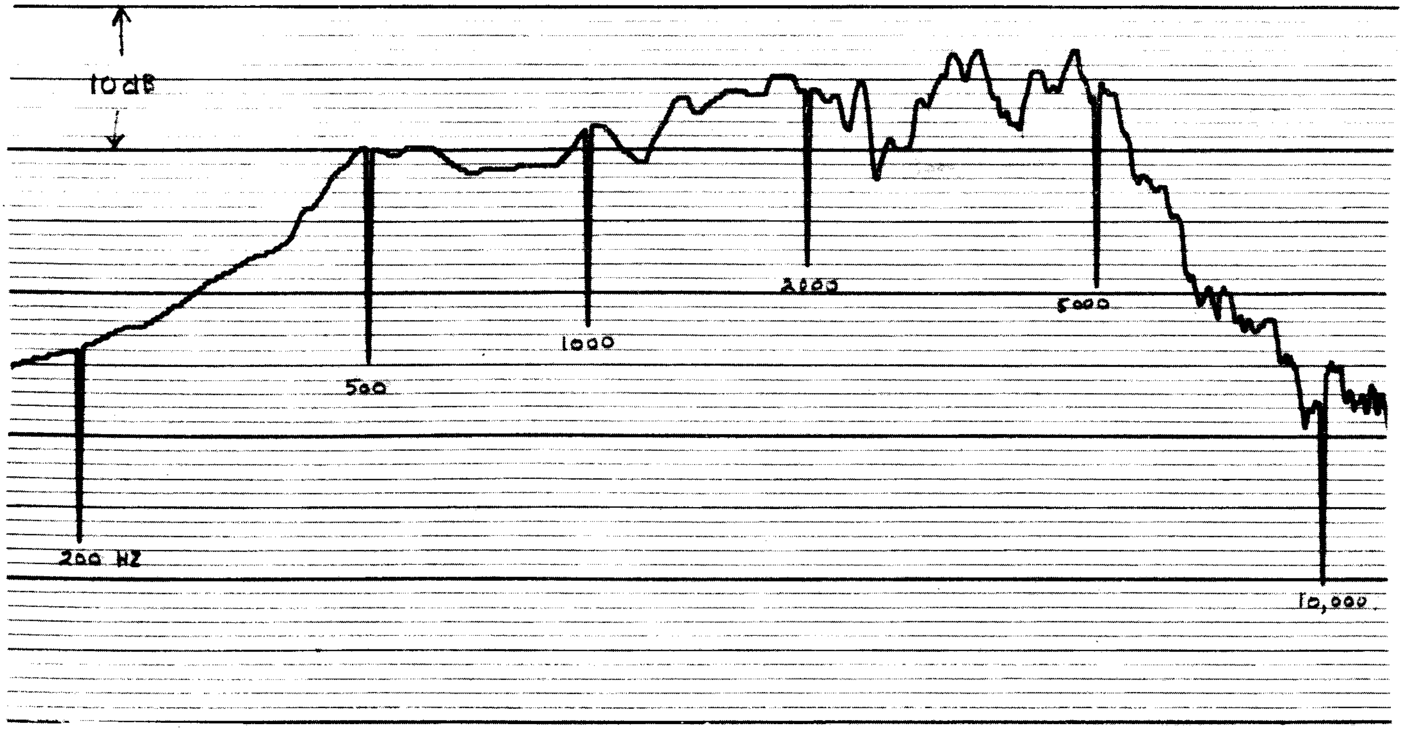

Fig. 3 - Acoustical response of one of the loudspeakers: glide-tone recording

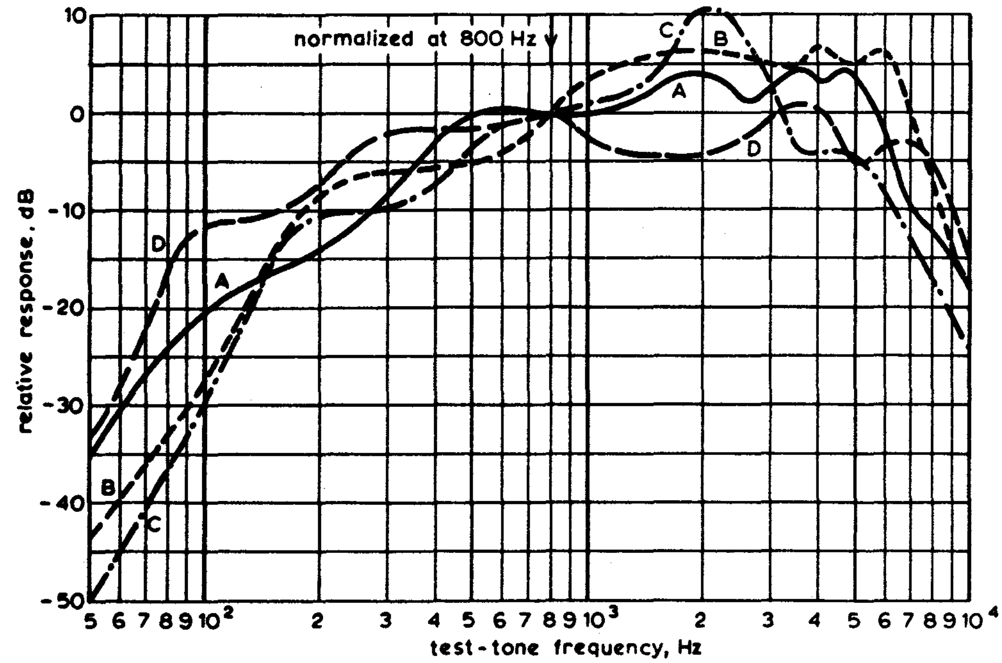

Fig. 4 - Measured acoustical response of loudspeakers (smoothed versions)

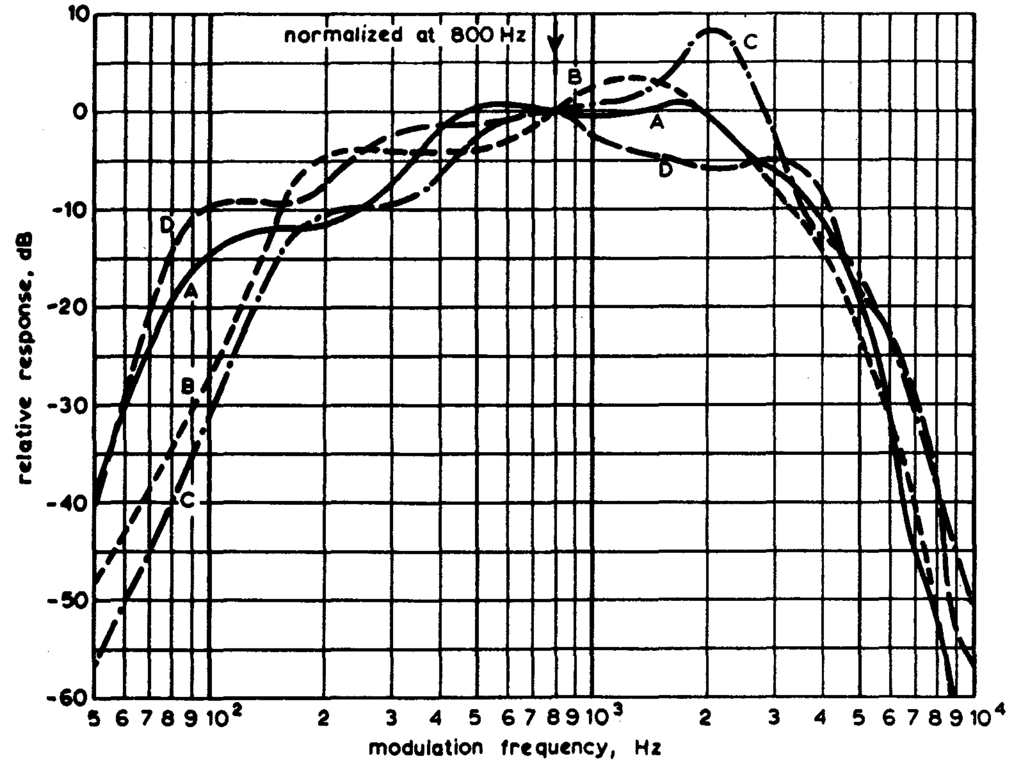

Fig. 5 - Overall (electrical plus loudspeaker) response of receivers (m.f. band)

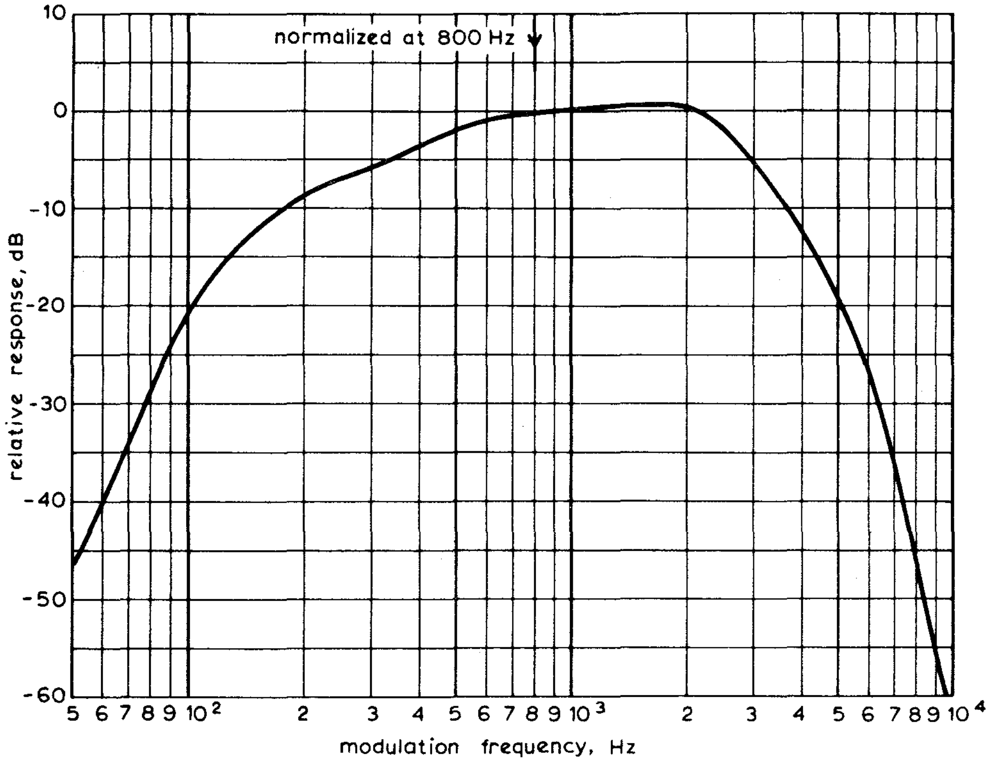

Fig. 6 - Overall response: average result for four receivers

6. OVERALL FREQUENCY RESPONSE

By combining the measured electrical response of the receivers (Fig. 2) with the acoustical responses of their loudspeakers (Fig. 4), we obtain the set of curves shown in Fig. 5. These curves can be regarded as smoothed versions of the overall amplitude-versus-frequency responses of the receivers. Particular features are summarized in Table 3.

TABLE 3

Overall Response Characteristics

Receiver	Response at given modulation frequency relative to response at 800 Hz, dB			Average rate of attenuation between 5 kHz and 10 kHz, dB per octave
	100 Hz	4·5 kHz	9 kHz	
A	−14·5	−15	−60·5	49
B	−27	−18	−63	48
C	−31	−14·5	−44·5	37
D	− 9·5	−14·5	−53	44

Allowing for the arbitrary normalizing frequency of 800 Hz, a rather striking feature of the overall results is the general similarity of the response characteristics. Indeed, perhaps this is not coincidental and that to achieve a good balance between an aesthetically pleasing reproduction and a reasonable degree of immunity from adjacent-channel transmissions in the m.f./l.f. bands the manufacturer is forced towards achieving an overall frequency response of the general form shown in Fig. 5.

To conclude, the single-curve shown in Fig. 6 is the geometric mean of the measured overall responses of the four receivers. It seems likely that this curve is a good approximation to the average characteristics of many existing a.m. receivers, in spite of the small sample of receivers used for the estimate.

7. ADJACENT-CHANNEL INTERFERENCE

It is expected that the slope and relative level of the overall frequency response characteristic, at a modulation frequency commensurate with the carrier frequency spacing between adjacent-channels, will be an important factor controlling the susceptibility of the receiver to adjacent-channel interference. To test this relationship, an attempt was made to correlate the objectively measured levels of response for the four receivers with subjective measurements of their adjacent-channel protection ratios.

Briefly, the subjective measurements were obtained by tuning a receiver to a programme-modulated carrier (the wanted programme) and then raising the level of a second programme-modulated carrier on an adjacent channel (the interfering programme) until the listener decided that the interference was 'perceptible'.* The ratio of the wanted-to-interfering input signal levels (protection ratio) was recorded for this condition. Speech was used for the wanted programme and continuous light music for the interfering programme. Measurements were carried out for carrier spacings of ±7 kHz, ±8 kHz and ±9 kHz. In one series of tests the audio bandwidth of both the wanted and interfering programmes was unrestricted but in a second series the audio bandwidths were restricted to 4·5 kHz. The protection ratios obtained by six listeners were averaged (geometric means).

Fig. 7 shows the measured adjacent-channel protection ratio plotted against the relative level of the overall frequency response of the receiver at a modulation frequency equal to that of the adjacent-channel carrier spacing. Fig. 7(*a*) refers to the tests in which the audio bandwidths of the programmes were unrestricted and Fig. 7(*b*) to the tests in which the audio bandwidths were restricted to 4·5 kHz. Each figure includes results for all the channel spacings used (7 kHz to 9 kHz) and for all the receivers; the latter are identified by the different plot-point symbols.

The correlation between the parameters used is seen to be good and an attempt has been made to establish an empirical relationship by drawing an average curve through the plot-points (the dashed lines in Fig. 7). Although significantly related, however, the relative response of a receiver at the adjacent-channel frequency cannot be expected to provide an accurate objective measure of its protection ratio which could be universally applied to every receiver, irrespective of the shape of the overall response characteristic or of the transmission standards. This is borne out, for example, by the differences between the results of Fig. 7(*a*) and Fig. 7(*b*). A significant improvement in the adjacent-channel protection ratio is obtained and the relationship is more linear, for low levels of response, when the audio bandwidth of the interfering transmission is restricted to 4·5 kHz. At higher levels of response, however, the subjective influence of the audio-frequency components of the interfering programme greater than 4·5 kHz appear to be insignificant. A possible explanation is that, under these conditions, the continuous whistle due to the interfering carrier becomes the dominant feature of the perceived interference, and the strength of the carrier whistle is, of course, unaffected by restricting the audio bandwidth of the modulation.

8. CONCLUSIONS

The overall frequency response characteristics of four a.m. receivers were found to be of similar form, although at intermediate stages in the receiver, greater differences were apparent. Below 300 Hz, the overall characteristic is largely controlled by the base-cut characteristic of the loudspeaker response. Also, the influence of the acoustical element on the overall characteristic above 7 kHz is at least as great as that of the r.f./i.f. response of the receiver.

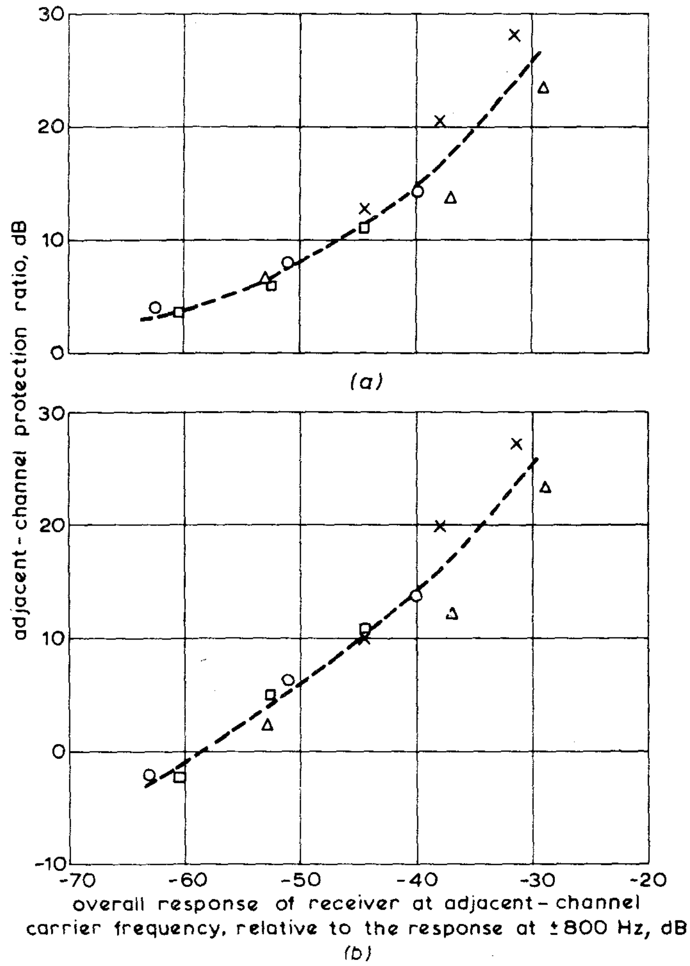

Fig. 7 - Measured relation between adjacent-channel protection ratio and overall response of receiver

(*a*) Unrestricted audio bandwidth (*b*) 4·5 kHz audio bandwidth

□ receiver A ○ receiver B × receiver C △ receiver D

The adjacent-channel protection ratio of a receiver can be predicted with reasonable accuracy (Fig. 7) from the relative level of its overall frequency response at the modulation frequency corresponding to the channel carrier spacing. Further empirical relationships would need to be established, however, to cope with any markedly different changes in the shape of the overall response characteristic which may occur in future receivers, and with different subjective criteria or transmission standards.

9. REFERENCE

1. SHORTER, D.E.L., GILFORD, C.L.S., HARWOOD, H.D. The acoustic design and performance of a new free-field sound measurement room. BBC Engineering Monograph, No. 59, Sept. 1965.

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* Corresponding to Grade 3 on the E.B.U. six-point impairment scale.

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